Information Disclosure Statement

Applicants filed a Supplemental IDS on June 5, 2009. It is respectfully requested that an initialed copy of the IDS be provided to Applicants to confirm consideration thereof.

Rejections Under 35 U.S.C. § 103

Claims 33-38, 40-47 and 49-61 were rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent No. 4,942,539 issued to McGee et al. (hereinafter "McGee") in view of "*Multisensory Visual Servoing by a Neural Network*" by Wei et al. (hereinafter "Wei").

Claim 50 is independent so will be discussed before the claims that depend therefrom. Claim 50 recites:

> A method useful in three-dimensional pose estimation for use with a single camera mounted to a movable portion of a robot, the method comprising: capturing a two-dimensional image of a volume containing a target object; locating a number of features in the captured image of the target object; and determining an object space-to-camera space transformation for the target object based at least in part on a position of at least some of the located features using only the single captured image and an algorithm that employs a known or determinable physical relationship between at least some of the located features.

McGee teaches a single camera for automatically determining the position and orientation of an object by utilizing as few as a single digital image generated by as few as a single camera with the use of structured light.

The Office states that:

[t]he digital image contains at least three non-colinear features of the object that equates to the single camera of this application (see abs. and fig. 1 as see below, particularly the single camera and "a programmed computer together with reference data and camera calibration data to provide at least three non-parallel 3-D lines. The 3-D lines are utilized by an iterative

algorithm to obtain data relating to the position and orientation of the object in 3-D space.") See Office Action page 10.

Respectfully, Applicants do not understand what this statement means or how three non-collinear features in an image can *equate* to a single camera. Applicants respectfully request clarification of such statement.

The Office goes on to state that McGee does not teach certain limitations which are purportedly taught by the secondary reference Wei. Office Action, page 10, final sentence. In particular, the Office appears to rely on Wei for teaching capturing images of a volume containing a target object, determining an object space-to-camera space transformation for the target object based at least in part on a position of at least some of the located features using only the captured image and an algorithm that employs a known or determinable physical relationship between at least some of the located features. Office Action, page 11. To support such the Office equates the variables roll, pitch and yaw set out in table I of Wei as the known or physical relationship between features, and purportedly page 277 cols 1-2. Id. However, the variable roll, pitch and yaw are *Cartesian motion* parameters for movement of the *end-effecter*, *not features* of the *object*, let alone a known or determinable physical relationship between located features of the object. Such is clearly described at page 276, col. 2, under heading II. A. In particular, Wei teaches that rigid motion is fully described via a rotation matrix and translation vector, and row, pitch, yaw or Euler angles are convenient representations for the rotation matrix. Id. Notably, the discussion at page 277, col. 1-2 heading B relied on by the Office does not appear to address the roll, pitch or yaw parameters.

Additionally, McGee and Wei take fundamentally different approaches to machine vision. Wei expressly teaches away[1] from calibration, distinguishing itself from

[1] MPEP 2143, A, Example 1 (The Court stated that "[d]espite the fact that each of the elements of the Adams battery was well known in the prior art, to combine them as did Adams required that a person reasonably skilled in the prior art must ignore" the teaching away of the prior art that such batteries were impractical and that water-activated batteries were successful only when combined with electrolytes detrimental to the use of magnesium electrodes. *Id.* at 42-43, 50-52, 148 USPQ at 480, 483. "When the prior art teaches away from combining certain known elements, discovery of successful means of combining them is more likely to be nonobvious."*KSR*, 550 U.S. at ___, 82 USPQ2d at 1395).

traditional computer vision methods which require both the sensors and their mounting parameters to be calibrated in advance. See Wei, page 276, col. 1, abstract and section I, first full paragraph. As explained in Applicants' last response, Wei requires multiple cameras and teaches the use of stereo vision to produce multiple images. See Wei, page 276, col. 2 second full paragraph. Wei also relies on a neural network to process information. Wei also appears to focus on motion of the end-effecter, rather than determining position and orientation of the object relative to the end-effecter. See Wei, page 276, abstract and col. 2, second full paragraph ("end-effecter's Cartesian motion"), and page 277, cols. 1-2. In contrast, McGee teaches an approach which can use a single camera and a single image, and appears to employ conventional digital computers to perform image processing. Also in contrast to Wei, McGee requires camera calibration. See McGee, col. 5, lines 53-66. Further, McGee appears to focus on determining the position and orientation of the object, rather than relying iteratively assessing the motion of the end-effecter.

In sum, there is no teaching, motivation or suggestion to combine the teachings of McGee and Wei, nor does the Office offer any. See MPEP 2141[2] In any case, the fundamental principal of operation of these references, as well as their specific teachings, appear to be completely inconsistent with one another. To combine the teachings, one would not only have to *ignore* the specific teachings of at least one of these references, but would also have to *modify the principal of operation* of at least one of these references. See MPEP 2141 and 2143.

Claim 33 depends from claim 50 and further recites, *inter alia* "determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame."

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[2] ("The key to supporting any rejection under 35 U.S.C. 103 is the clear articulation of the reason(s) why the claimed invention would have been obvious. The Supreme Court in *KSR* noted that the analysis supporting a rejection under 35 U.S.C. 103 should be made explicit. The Court quoting *In re Kahn,* 441 F.3d 977, 988, 78 USPQ2d 1329, 1336 (Fed. Cir. 2006), stated that "'[R]ejections on obviousness cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness.'" *KSR*, 550 U.S. at ___, 82 USPQ2d at 1396.").

As explained above, claim 50 is allowable over McGee and Wei. The Office relies on Wei for purportedly teaching capturing a number of images of a calibration object and determining intrinsic and extrinsic parameters of the camera. Office Action, pages 3-4. However, Wei *expressly teaches away* from any calibration. See Wei, page 276, col. 1, abstract and section I, first full paragraph. Further, the Office relies on the two images captured by the stereo cameras of Wei. Office Action page 3. However, as explained in Applicants' last response, the claims are directed to a method employing a single camera. Thus, reliance on the stereo camera of Wei is misplaced.

Claim 34 depends from claims 33 and 50 and further recites "positioning the camera with respect to the calibration object." As explained above, claims 50 and 33 are allowable over McGee and Wei. The Office asserts that Wei teaches positioning the camera with respect to a calibration object, relying on Figures 2 and 3 and page 276, second paragraph lines 1-5 and col. 2, section II. Office Action page 5.

Wei *expressly teaches away* from calibration. Thus, it appears impossible to contend that Wei teaches positioning a camera relative to a *calibration* object. There is no basis for contending such, and such contention requires *ignoring* the clear teachings of Wei.

Claim 35 depends from claims 33, 34 and 50 and further recites "positioning the camera orthogonally with respect to a ruled template with a number of features, where a known or determinable physical relationship exists between at least some of the features."

As explained above, claims 50 and 33 are allowable over McGee and Wei. The Office asserts that Wei teaches positioning the camera orthogonally with respect to a calibration object, relying on Figures 2-4 and page 276, second paragraph lines 1-5 and col. 2, section II. Office Action page 5. In particular, the Office alleges that Figure 3 shows the camera mounted orthogonally with respect to a ruled template. Id.

Applicants note that Wei actually teaches *two* cameras, not *one*. Figure 3 of Wei is an isometric or perspective view, and does not show the relative position or orientation of the cameras with respect to any object or frame of reference. Hence, it is impossible to conclude that the cameras in Wei are orthogonal to a ruled template. The Office does not identify any object in Wei as representing a ruled template, nor even allege that Wei teaches use of a ruled

template. Further, since Wei *expressly teaches away* from calibration, it appears impossible to contend that Wei teaches positioning a camera relative to a *calibration* object. There is no basis for contending such, and such contention requires *ignoring* the clear teachings of Wei. The Office further relies on the roll, pitch and yaw variables as constituting the physical features. As explained above in reference to claim 50, such are parameters indicative of the *movement of the end-effecter* rather than features of the object or relationship between features of the object.

Claim 36 depends from claims 33, 34 and 50 and further recites "wherein positioning the camera with respect to the calibration object comprises positioning the camera with respect to a sample of a type of object the robot will manipulate, the sample having a number of features, where a known or determinable physical relationship exists between at least some of the features."

As explained above, claims 50 and 33 are allowable over McGee and Wei. The Office asserts that Wei teaches positioning the camera orthogonally with respect to a calibration object, relying on Figures 2-4 and page 276, second paragraph lines 1-5 and col. 2, section II. Office Action page 6.

As explained in reference to claim 35, Wei not only doesn't teach positioning a camera with respect to a calibration object but actively teaches away from calibration. Also as explained in reference to claim 35, the roll, pitch and yaw variables do not identify physical parameters of the object, but rather are parameters of the *movement of the end-effecter*.

Claim 37 depends from claims 33, 34 and 50 and further recites "wherein capturing a number of images of a calibration object by the camera comprises capturing at least one image at each of a plurality of positions spaced perpendicularly from the calibration object."

As explained above, claims 50 and 33 are allowable over McGee and Wei. The Office relies on the passage of Wei at page 276, col. 1, third paragraph (*i.e.*, "used an eye-on-hand configuration to track an object on a conveyor"). Again, the Office's reliance on Wei with respect to calibration is completely misplaced as Wei *clearly teaches against calibration*.

Claim 38 depends from claims 33, 34 and 50 and further recites "wherein capturing a number of images of a calibration object by the camera comprises capturing at least one image at each of a plurality of different orientations with respect to the calibration object."

As explained above, claims 50 and 33 are allowable over McGee and Wei. Again, the Office's reliance on Wei with respect to calibration is misplaced as Wei clearly *teaches against calibration*. Additionally, the Office fails to appreciate the difference between the "positions" along the conveyor line, and the recited "orientations" of claim 38.

Claim 40 depends from claims 33 and 50 and further recites "wherein determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame comprises determining a respective translation component along three orthogonal axes, and a respective rotation component about the three orthogonal axes."

As explained above, claims 50 and 33 are allowable over McGee and Wei. The Office relies on Wei for purportedly teaching determining both intrinsic and extrinsic parameter of the camera from images of the calibration object. Office Action, page 7.

Wei teaches the use of two cameras and laser finders to calculate an *object's* extrinsic parameters. Wei does *not* use *camera* calibration information to determine an object's extrinsic parameters, and again, Wei clearly *teaches away from calibration of the cameras*. See Wei, page 276, col. 1, abstract and section I, first full paragraph.

Claim 41 depends from claims 33 and 50 and further recites "determining a camera space-to-tool space transformation based at least in part on at least two of the number of images captured by the camera of the calibration object."

As explained above, claims 50 and 33 are allowable over McGee and Wei. As explained above in reference to claim 40, Wei not only fails to teach use of camera calibration information to determine a transformation, but actively *teaches away from calibration of cameras.* See Wei, page 276, col. 1, abstract and section I, first full paragraph.

Claim 42 depends from claims 33 and 50 and further recites "determining a camera space-to-tool space transformation based on single one of the number of images captured by the camera of the calibration object and on a number of physical coordinates of at least one feature of the calibration object."

As explained above, claims 50 and 33 are allowable over McGee and Wei. Wei appears to even mention using one image and one feature to calculate a camera space-to-tool transformation, and given the stereo camera and range finder set up would not appear to be amendable to such an approach. Also, as explained above in reference to claim 40, Wei not only fails to teach use of *camera calibration information* to determine a transformation, but actively *teaches away from calibration of cameras*. See Wei, page 276, col. 1, abstract and section I, first full paragraph.

Claim 43 depends from claim 50 and further recites, *inter alia,* "selecting a number of features from the captured image of the teaching object; and determining a set of object space coordinates for each of the selected features from the captured image of the teaching object."

As explained above, claim 50 is allowable over McGee and Wei. The Office contends that Wei teaches the additional limitations of claim 43, specifically relying on the abstract and Figure 4. Office Action, page 8. Figure 4 shows a stereo view of an object with two black blobs artificially marked thereon, but does not describe selecting such features nor determining a set of object space coordinates for each feature. Wei, page 279, col. 2, first full paragraph. The abstract generally describes using two kinds of sensor day, namely camera images and laser range data, as input to a multilayer feedforward neural network to associate the *direct transformation from the sensory data to the required motions*. Wei, page 276, abstract and col. 2 first full paragraph. Such not only fails to teach the above quoted limitations, but strongly suggests that no intermediate transformations are calculated. If the Office persists in this rejection, Applicants' respectfully request that the Office point out particularly where the above quoted limitations may be found in Wei or at least explain how the Office is inferring such.

Claim 44 depends from claims 43 and 50 and further recites "wherein selecting a number of features from the captured image of the teaching object comprises selecting six features from the captured image of the teaching object."

As explained above, claims 50 and 43 are allowable over McGee and Wei. The Office contends that Wei teaches the additional limitations of claim 43, specifically relying on Figure 4 and discussion of imaging while an object moves along a conveyor. Office Action,

pages 8-9. However, the cameras in Wei stay fixed, hence while separate images may be captured of an object at each of a plurality of positions as the object translates relative to the cameras. Such appears to simple capture the same features from multiple different orientations. Notable, claim 44 recites selecting six features from *the captured image*, singular, *not* plural, thus Wei does not teach or suggest the limitation of claim 44.

Claim 45 depends from claims 43 and 50 and further recites "determining an object space-to-camera space transformation defining a transformation between an object space reference frame and the camera space reference frame."

As explained above, claims 50 and 43 are allowable over McGee and Wei. The Office relies on Wei for teaching this additional limitation. Office Action, page 9. In particular, the Office interprets "space-to-training space transformation . . . as from object to the camera/range finders, to the training and to the geometric transformation" and has interpreted "a space reference frame . . . as from the reference position to the algorithm module to the camera/range finders, to the shift and finally to the geometric transformation." Id.

Respectfully, Applicants' do not understand what such means. Reference frames are commonly understood as a coordinate system in which one works or takes measurements. Transformations are essentially mathematical based definitions that allow mapping between various reference frames. The Office's interpretation of reference frame does not appear to make sense under any conventional understanding of the term. Clarification is respectfully requested.

In any case, Wei requires two cameras and two laser range finders, which are not co-located. (In fact, stereo placement is required.) Hence, there appears to be no object space-to-camera space transformation. Further, as described in reference to claim 43, Wei teaches *direct transformation from the sensory data to the required motions*. Wei, page 276, abstract and col. 2 first full paragraph. Such not only fails to teach the above quoted limitation, but strongly suggests that no intermediate transformations are calculated.

Claim 46 depends from claims 45, 43 and 50 and further recites "determining a position and an orientation of an object frame in the tool frame reference frame based at least in part on the object frame-to-camera space and camera space-to-tool space transformations."

As explained above, claims 50, 43 and 45 are allowable over McGee and Wei. The Office relies on Wei for teaching the additional limitation of claim 46. Office Action, page 9. In particular, the Office states that "the reference frame has been considered as position frame and table II for position and orientation." Id. Again, the interpretation appears highly questionable. It is unclear how a table of data is interpreted to be part of a reference frame.

In any case, Wei teaches *direct transformation from the sensory data to the required motions*. Wei, page 276, abstract and col. 2 first full paragraph. Such not only fails to teach the above quoted limitation, but strongly suggests that no intermediate transformations are calculated.

Claim 47 depends from claims 46, 45, 43 and 50 and further recites "providing the position and orientation of the object frame to the robot; and training an intended operation path inside the object frame."

As explained above, claims 50, 43, 45 and 46 are allowable over McGee and Wei. The Office relies on Wei for teaching the additional limitation of claim 47. Office Action, page 9-10. While Wei appears to drive the robot, Wei appears to simply provide required motions directly to the robot. Wei, page 276, abstract and col. 2 first full paragraph. Thus, there would be no reason for Wei to provide position and orientation of the object frame to the robot as recited in claim 47. Nor would such have to take place in the object frame, as opposed to the robot or tool reference frame.

Claim 49 depends from claim 50 and further recites, *inter alia*, "adjusting a position of the movable portion of the robot if the number of features located in the captured image of the target object is determined to be an insufficient number of features."

As explained above, claim 50 is allowable over McGee and Wei. The Office relies on Wei for teaching the additional limitation of claim 49. Office Action, page 10. In particular, the Office appears to be relying on the two images captured by the stereoscopic cameras. Id. However, the stereoscopic cameras capture two images without regard to the number of features located. Wei does not appear to address what would happen if an insufficient number of features were located. In fact, Applicants' representative is unable to find any mention in Wei of a minimum number of features.

Claim 51 depends from claim 50 and further recites "determining at least one movement of the robot that orients the camera orthogonally with respect to the target object based at least on part on the object space-to-camera space transformation."

As explained above, claim 50 is allowable over McGee and Wei. The Office relies on Wei for teaching the additional limitation of claim 51. Office Action, pages 11-12.

As explained above with reference to claim 35, Applicants note that Wei actually teaches *two* cameras, not *one*. Figure 3 of Wei is an isometric or perspective view, and does not show the relative position or orientation of the cameras with respect to any object or frame of reference. Hence, it is impossible to conclude that the cameras in Wei are positioned orthogonally, and one can only wonder how both cameras can be positioned orthogonally when the cameras must be in a stereoscopic arrangement.

Claim 52 depends from claims 51 and 50 and further recites "determining a position of the object frame in the tool space reference frame; and providing an object frame to the robot."

As explained above, claims 50 and 51 are allowable over McGee and Wei. The Office relies on Wei for teaching the additional limitation of claim 52. Office Action, page 12.

Wei appears to simply provide required motions directly to the robot. Wei, page 276, abstract and col. 2 first full paragraph. Thus, there would be no reason for Wei to provide a position of the object frame in the tool space reference frame nor to provide an object frame to the robot as recited in claim 52.

Claim 53 is independent and recites, *inter alia,* "means for calibrating the camera, by: determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame."

The Office relies on Wei for purportedly teaching the above quoted limitations. Office Action, page 12. As discussed above in reference to claim 50, as well as other claims,

Wei not only fails to teach such, but actively *teaches away* from *camera calibration*. See Wei, page 276, abstract, col. 1, section I first full paragraph.

Claim 53 also recites "locating at least six features in the captured image of the target object." Again the Office relies on Wei for the above quoted limitation. Office Action page 13. As explained above in reference to claim 44, the cameras in Wei stay fixed, hence while separate images may be captured of an object at each of a plurality of positions as the object translates relative to the cameras. Such appears to simple capture the same features from multiple different orientations. Wei does not appear to teach or suggest selecting six features from *the captured image*, singular, *not* plural, thus Wei does not teach or suggest the limitation of claim 53.

Claim 53 further recites, *inter alia,* "determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features in solely the captured image using an algorithm that employs a known or determinable physical relationship between at least some of the located features." Again the Office relies on Wei for the above quoted limitation. Office Action pages 13-14. As previously explained, Wei appears to simply provide required motions directly to the robot. Wei, page 276, abstract and col. 2 first full paragraph. Thus, there would be no reason for Wei to determine an object space to a camera space transformation. In fact, Wei employs two cameras, and the Office fails to consider how such a transformation could possibly make sense

Claim 54 depends from claim 53 and further recites, *inter alia*, "selecting a number of features from the captured image of the teaching object; determining a set of object space coordinates for each of the selected features from the captured image of the teaching object; and determining an object space-to-camera space transformation defining a transformation between an object space reference frame and the camera space reference frame."

Again the Office relies on Wei. Office Action, page 14. Claim 54 however is patentable over the cited references for similar reasons as those explained above in reference to claim 43.

Claim 57 depends from claims 50 and 53 and further recites "adjusting a position of the movable portion of the robot if the number of features located in the captured image of the

target object is determined to be an insufficient number of features." Claim 57 is patentable over the references for similar reasons as those explained above with reference to claim 49.

Claim 58 is independent and recites, *inter alia*, "means for calibrating the camera, by: determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame."

The Office relies on Wei for purportedly teaching the above quoted limitations. Office Action, page 15. As discussed above in reference to claim 50, as well as other claims, Wei not only fails to teach such, but actively *teaches away* from *camera calibration*. See Wei, page 276, abstract, col. 1, section I first full paragraph.

Claim 58 further recites, *inter alai*, "means for estimating a pose of a target object, by: locating at least five features in the captured image of the target object; and determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features using the captured image without any additional captured images and an algorithm that employs a known or determinable physical relationship between at least some of the located features."

The Office relies on Wei for purportedly teaching the above quoted limitations. Office Action, page 16. As discussed above, for example in reference to claim 53, while Wei may teach acquiring separate of an object at each of a plurality of positions as the object translates along a conveyor relative to the cameras, such appears to simple capture the same features from multiple different orientations. Wei does not appear to teach or suggest locating at least five features from *the captured image*, singular, *not* plural. Thus, Wei does not teach or suggest the above quoted limitation of claim 58.

Also as discussed above, for example in reference to claim 53, Wei appears to simply provide required motions directly to the robot. Wei, page 276, abstract and col. 2 first full paragraph. Thus, there would be no reason for Wei to determine an object space to a camera

space transformation. In fact, Wei employs two cameras, each of which would have their own reference frames. The Office fails to consider how such a transformation could possibly make sense.

Claim 59 depends from claim 58 and further recites "wherein the means for calibrating and the means for estimating a pose comprises at least one programmed computer." The Office relies on Wei for teaching such. Office Action, page 59. However, Wei clearly *teaches away* from calibration of the cameras. See Wei, page 276, abstract, col. 1, section I first full paragraph.

Claim 61 depends from claim 58 and further recites "adjusting a position of the movable portion of the robot if the number of features located in the captured image of the target object is determined to be an insufficient number of features."

The Office Action does not appear to provide any specific explanation of the rejection of claim 61. However, claim 61 is patentable over the references for similar reasons as those explained in reference to claims 49 and 57.

Conclusion

Applicants respectfully submit that the pending claims are in condition for allowance. Any remarks in support of patentability of one claim should not be imputed to any other claim, even if similar terminology is used. Any remarks referring to only a portion of a claim should not be understood to base patentability on that portion; rather, patentability must rest on each claim taken as a whole. Applicants do not acquiesce to each of the Examiner's rejections and to each of the Examiner's assertions regarding what the cited references show or teach, even if not expressly discussed herein.

If the undersigned attorney has overlooked a relevant teaching in any of the references, the Examiner is requested to point out specifically where such teaching may be found. In light of the above remarks, Applicants respectfully submit that all pending claims are allowable. Applicants, therefore, respectfully request that the Examiner reconsider this application and timely allow all pending claims. The Examiner is encouraged to contact the undersigned by telephone to discuss the above and any other distinctions between the claims and

the applied references, if desired. If the Examiner notes any informalities in the claims, the Examiner is encouraged to contact the undersigned by telephone to expediently correct such informalities.

Respectfully submitted,

SEED Intellectual Property Law Group PLLC

/Frank Abramonte/
Frank Abramonte
Registration No. 38,066

FXA:sc

701 Fifth Avenue, Suite 5400
Seattle, Washington 98104
Phone: (206) 622-4900
Fax: (206) 682-6031

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